

SQ-MIN-200

NANO-POWER TILT AND VIBRATION SENSOR



FUNCTION

- Normally closed at rest
- Omnidirectional movement sensing
- Chatters open / closed when tilted or vibrated in any direction regardless of orientation

APPLICATIONS

- Motion triggered wake-up
- GPS tracking, RFID, vehicle electronics
- Security, anti-tamper, anti-theft, alarms

DESCRIPTION

The SQ-MIN-200 series sensor acts like a normally closed switch which chatters open and closed as it is tilted or vibrated. Unlike other rolling-ball sensors, the 200 is truly an omnidirectional movement sensor. It will function regardless of how it is mounted or aligned.

When at rest, it normally settles in a closed state. When in motion, it will produce continuous on/off contact closures. It is sensitive to both tilt (static acceleration) and vibration (dynamic acceleration). The sensor can be easily used to produce a series of CMOS or TTL level logic level or pulse train using a single resistor to limit current. The signal level can be read directly by a digital input. This can be used to interrupt (wake up) a microcontroller or can be counted to estimate the amount and duration of activity. The sensor is fully passive, requires no signal conditioning, and draws as little as 50 nA of continuous current.

PATENTS

United States: 7326866, 7067748, 7326867, Taiwan: I334019, Korea: 10-0946453, Mexico: 275272. Patents pending.

FEATURES

- Simple Interface No signal conditioning required
- Surface Mount RoHS & REACH compliant, lead free, Halogen free
- Made in USA fully automated production, 100% testing, worldwide quality and price leader
- Ultra Miniature Size 1.9 mm x 3.6 mm
- Nano-power As little as 50 nA
- Industrial Rated 10 year life, -40° to 85° C

FUNCTIONAL DIAGRAM







Updated: 2014-01-16



SQ-MIN-200

NANO-POWER TILT AND VIBRATION SENSOR

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SQ-MIN-200

NANO-POWER TILT AND VIBRATION SENSOR

THEORY OF OPERATION

The SQ-MIN-200 series sensor acts like a normally closed switch which chatters open and closed as it is tilted or vibrated. Note that the SQ-MIN-200 is <u>not guaranteed to be closed</u> – occasionally the sensing mechanism may remain open when at rest. The engineer should design his or her software to look for high-to-low and low-to-high edge transitions rather than an open or closed state of the switch.

CHARACTERISTICS

PARAMETER	Min	Мах	CONDITIONS
Shock Survival		5,000 g	5x, 0.1 ms half-sin, any axis
Storage Temperature	-40 °C	85 °C	
Supply Voltage Range	0.5 V	12 V	
Current Sink*	50 nA	10 mA	

* Current consumption is determined by the resistance of the application circuit and the supply voltage.

DIMENSIONS

PHYSICAL SIZE



Symbol	DESCRIPTION	ММ	TOLERANCE
D	Length	3.60	±0.1
Е	Diameter	1.95	±0.1
F	Terminal Width	0.40	±0.1

PCB LANDING

Symbol	DESCRIPTION	ММ
А	Pitch	3.6
В	Pad Length	1.0
С	Pad Width	1.5



*Note: Alternative layouts may be used to optimize size or manufacturability

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SQ-MIN-200

NANO-POWER TILT AND VIBRATION SENSOR

PRODUCT COMPARISON

GRADE	Assembly Method	SEALED	WASHABLE	RoHS	Operating Temperature	CYCLES *	SERVICE Life (YRS)
Ι	Reflow Solder: 260° C peak Hand Assembly: 315° C peak, 2 -3 seconds on end terminal	Yes	Yes	Yes	-40° to +85° C	1 Billion	10
С	Reflow Solder: 260° C peak Hand Assembly: 315° C peak, 2 -3 seconds on end terminal	Yes	Yes	Yes	-25° to +70° C	1 Billion	5

*Test conditions: 0.5 gRMS, 5 to 200 Hz flat spectrum

ORDERING GUIDE

PART NUMBER	PACKAGING CODE	COMPLETE ORDER NUMBER
SQ-MIN-200-C	TR - Tape on Reel	SQ-MIN-200-CTR
SQ-MIN-200-I	CT - Cut Tape TR - Tape on Reel	SQ-MIN-200-ICT SQ-MIN-200-ITR

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SQ-MIN-200

NANO-POWER TILT AND VIBRATION SENSOR

LIMITATIONS AND WARNINGS

This product is not designed for use in life support and/or safety equipment where malfunction of the product can reasonably be expected to result in personal injury or death. Buyer uses this product in such applications at Buyer's own risk and agrees to defend, indemnify, and hold harmless SignalQuest, LLC from any and all damages, claims, suits, or expenses resulting from such misuse.

TESTING

The performance of each sensor is verified through build-time testing.

SYSTEM INTEGRATION TESTING

Thorough testing should be carried out prior to product release to ensure system integration has not introduced unforeseen problems. The system integrator assumes the ultimate responsibility for the safety of the target application.

NOTICE

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FUNCTION

• On / off shock & acceleration sensing

APPLICATIONS

- Damage detection for medical products
- Munitions
- Security, anti-tamper, anti-theft, alarms

DESCRIPTION

The SQ-ASx series sensors act like acceleration sensitive switches that open or close when accelerated past an acceleration threshold.

The sensor can be used to produces CMOS or TTL pulses to interrupt (wake up) a microcontroller. The sensor is fully passive, requires no signal conditioning, and operates with zero current or only 50 nA depending on model.

PATENTS

Patented. United States: 8367952, China: 101960316. Patents pending.

FEATURES

- Miniature Size 3.3 mm x 6.9 mm
- Simple Interface No signal conditioning required
- Made in USA fully automated production, 100% testing
- Fast Response < 100 uS
- Multiple Sensitivities 10 G to 1400 G standard
- Zero-power or nanopower
- Industrial Rated 10 year life, -40° to 85° C

DATASHEET

SQ-ASX SERIES

ON/OFF SHOCK AND ACCELERATION SENSOR

FUNCTIONAL DIAGRAMS



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SQ-ASX SERIES

ON/OFF SHOCK AND ACCELERATION SENSOR

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SQ-ASX SERIES

ON/OFF SHOCK AND ACCELERATION SENSOR

CHARACTERISTICS

PARAMETER	MIN	Мах	CONDITIONS
Shock Survival		5,000 g	5x, 0.1 ms half-sin, any axis
Storage Temperature	-40° C	85° C	
Supply Voltage Range	0.5 V	12 V	
Current Sink*	50 nA	10 mA	

* Current consumption is determined by the resistance of the application circuit and the supply voltage.

DIMENSIONS FOR ASA & ASC

PHYSICAL SIZE



Symbol	DESCRIPTION	ММ	TOLERANCE
А	Length	6.8	±0.25
В	Diameter	3.3	±0.1
С	Terminal Width	0.8	±0.25
D	Solder Nub Diameter	0.9	±0.25
Е	Solder Nub Length	0.4	±0.1
F	Terminal Width 2	.4	±0.25

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SQ-ASX SERIES

ON/OFF SHOCK AND ACCELERATION SENSOR

Length

Diameter

Terminal Width

Solder Nub Diameter

Solder Nub Length

DESCRIPTION

MM

6.8

3.3

0.8

0.9

0.4

TOLERANCE

±0.25

 ± 0.1

 ± 0.25

 ± 0.25

 ± 0.1

DIMENSIONS ASB, ASD, & ASE



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SQ-ASX SERIES

ON/OFF SHOCK AND ACCELERATION SENSOR

EXAMPLE PCB LANDING

RECOMMENDED PCB LANDING		ALTERNATE, PCB CUTOUT LANDING (USE FOR LOV	VEST PROFILE)		
Symbol	DESCRIPTION	ММ		Symbol	DESCRIPTION	ММ
А	Pitch	6.0		А	Recess Length	7.25
В	Pad Length	1.2		В	Pad Length	0.8
С	Pad Width	2.1		С	Pad Width	1.5
	1			D	Recess Width	3.6
C B B			B A-	ers as necessary -		

*Note: Alternative layouts may be used to optimize size or manufacturability

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SQ-ASX SERIES

ON/OFF SHOCK AND ACCELERATION SENSOR

THEORY OF OPERATION

Acceleration causes a spring and/or weight to either open or close a circuit depending on model.

FUNCTIONAL BEHAVIOR

SQ-ASA

The SQ-ASA series sensor is a normally <u>closed</u> device. It is designed to be sensitive only in one direction. However, it will exhibit some off axis sensitivity. Typical cross axis open signals are in the 2 - 8 mS range, where on axis open signals are proportional to the duration of acceleration above the threshold.

SQ-ASB

The SQ-ASB series sensor is a normally <u>closed</u> device. It is designed to be sensitive in all directions. It is about 4 times more sensitive off axis than on axis. Typical cross axis open signals are in the 2 - 8 mS range, where on axis open signals are proportional to the duration of acceleration above the threshold. **NOTE**: If better accuracy is required, choose the cross axis specification that matches your requirements and use two sensors at 90 degrees to one another, logically "OR'ed" together.

SQ-ASC

The SQ-ASC series sensor is a normally **<u>open</u>** device. It is designed to be sensitive only in one direction and is very immune to cross axis acceleration. Only if a cross axis event is 10 times greater than the rated threshold may the sensor trigger in a cross axis mode.

SQ-ASD

The SQ-ASD series sensor is a normally <u>open</u> device. It is designed to be sensitive in all directions. The sensor will trigger radially or in the terminal $1 \rightarrow 2$ direction when acceleration is applied. In the terminal $2 \rightarrow 1$ direction, the sensor will trigger after the acceleration is removed (rebound effect). **NOTE**: If using the rebound trigger in the $2 \rightarrow 1$ direction is not appropriate for the application, mount two sensor parallel in opposite directions.

SQ-ASE

The SQ-ASE series sensor is a normally <u>open</u> device. It is designed to be sensitive in a radial direction. The sensor will trigger radially when acceleration is applied. **NOTE**: To achieve an omnidirectional response mount two sensors at 90 degrees to one another in any plane, logically "OR'ed" together.

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SQ-ASX SERIES

ON/OFF SHOCK AND ACCELERATION SENSOR

PART COMPARISON

PART NUMBER	Туре	Sensitivity	ACCELERATION THRESHOLD (ON AXIS)
SQ-ASA-150	Normally closed	One axis, single sided	150 G
SQ-ASB-010	Normally closed	Omnidirectional	5 - 20 G
SQ-ASE-060	Normally open	Radial axis	60 G
SQ-ASE-100	Normally open	Radial axis	100 G
SQ-ASE-1400	Normally open	Radial axis	1400 G

PRODUCT COMPARISON

GRADE	Assembly Method	SEALED	WASHABLE	RoHS	Operating Temperature	CYCLES *	SERVICE LIFE (YRS)
Ι	Reflow Solder: 260° C peak Hand Assembly: 315° C peak, 2 -3 seconds on end terminal	Yes	Yes	Yes	-40° to +85° C	100,000	10
С	Reflow Solder: 260° C peak Hand Assembly: 315° C peak, 2 -3 seconds on end terminal	Yes	Yes	Yes	-25° to +70° C	100,000	5

*Test conditions: 0.5 gRMS, 5 to 200 Hz flat spectrum

Ordering Guide

PART NUMBER	PACKAGING CODE	EXAMPLE COMPLETE ORDER NUMBER
SQ-ASx-xxx-C	TR - Tape on Reel	SQ-ASA-150-CTR
SQ-ASx-xxx-I	CT - Cut Tape	SQ-ASB-010-ICT
	TR - Tape on Reel	SQ-ASE-060-ITR

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TESTING

The performance of each sensor is verified through build-time testing.

SYSTEM INTEGRATION TESTING

Thorough testing should be carried out prior to product release to ensure system integration has not introduced unforeseen problems. The system integrator assumes the ultimate responsibility for the safety of the target application.

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SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939



FUNCTION

LOW RANGE "RIL" MODEL

- \pm 70 ° dual axis angle measurement
- 360 ° single axis angle measurement

WIDE RANGE "RIW" MODEL

 Wide range 360 ° x 180 ° dual axis angle measurement

APPLICATIONS

- Platform and vehicle leveling
- Satellite dish and antenna alignment
- Machine control and monitoring
- Angle measurement and recording
- Computer input, head tracking, and mouse pointing

DESCRIPTION

The SQ-RI contains a high accuracy inclinometer, robust power conditioning and a CAN2.0B/J1939 interface controller all potted in an industrial enclosure. A Deutch DTF series connector is standard; M12, flying lead and other connector options are available.

FEATURES

- ± 0.1 ° and ± 0.01 ° resolution options
- IP65, IP67 and IP68 options
- Low temperature drift
- Factory calibrated angle output
- High reliability solid-state MEMS
- Digital filtering for stable measurement

ALTERNATE HOUSINGS

A variety of enclosures are available. Please consult the factory for different enclosures, connectors and cabling options.

THEORY OF OPERATION

The inclinometer uses two factory calibrated accelerometers to measure and compute angles made between its axes and the gravity vector. The trigonometric conversions between acceleration and angle are made by an onboard processor. Digital filtering reduces the impact of spurious acceleration and vibration on the reported angle.



LOW RANGE "RIL" MODEL

In **Dual-Axis Mode** the RIW sensor measures inclination between the earth and its X and Y axes with a range of $\pm 70^{\circ}$.

In **Single-Axis Mode** the RIW sensor measures full-scale rotation about the Z axis with a range of 360° . The sensor must be oriented such that the Z axis is parallel to the ground.

WIDE RANGE "RIW" MODEL

The sensor measures between earth and its X and Y axes with a range of 360 $^{\rm o}$ in one axis and 180 $^{\rm o}$ in the other.

CAN BUSSING OPTIONS

The SQ-RI supports CAN2.0 bus rates up to 1.0 Mbps and can be connected to the bus either in-line or on a tap. The CAN bus is internally terminated in models with a single connector





SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

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SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

PERFORMANCE CHARACTERISTICS

PARAMETER	SPECIFICATION	UNITS
Axes	2	
Case alignment	0.1	0
Accuracy	0.1	0
Zero point temp drift	0.005	°/°C
Settling time	0.1 / 0.5	S
Update rate	40	Hz
Nonlinearity	< 0.5	% FSR
Operating Temperature	-40 to 85	°C
Transverse sensitivity	< 1	% at 30°C
Operating Vibration	1.7	g_n^{l}
Shock Survivability	500	g_n
I/O ESD Protection - HBM	16	kV

ABSOLUTE MAXIMUM RATINGS

PARAMETER	Min	MAX	UNITS
Supply Voltage (-5R model)	-40	24	V _{dc}
Supply Voltage (-36R model)	-40	40	V _{dc}
Voltage on any I/O pin	-0.7	5.8	V _{dc}
	-4	16	V _{dc}
CAINH/CAINL	-11	11	mA
CANH-CANL Differential	-6	6	V _{dc}

ELECTRICAL CHARACTERISTICS

PARAMETER	Min	Түр	MAX	UNITS
Supply Voltage (-5R)	4.5		12	V _{dc}
Supply Voltage (-36R)	7		36	V _{dc}
Supply Current		50		mA
CAN Bus Rate		250	1000	kbps

¹ Where 1 g_n is approximately 9.80m/s²



SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

COMPARISON DATA FOR MODELS AND OPTIONS

RESOLUTION AND REPEATABILITY OPTIONS (P1 & P2)

PARAMETER	P1 Option	P2 OPTION (COMING SOON)	UNITS
Resolution	0.1	0.01	0
Null repeatability	0.1	0.05	0

RANGE & TEMPERATURE PERFORMANCE (SQ-RIL)

Based on SignalQuest inclinometer model SQ-SI-360DA

PARAMETER	SPECIFICATION		NOTES			
Angle range - Dual Axis Mode	\pm 70 ° (X and Y tilt)		± 70 ° (X and Y tilt) Dual axis X and Y tilt angle ranges with respect to horizontal.			nges with
Angle range - Single Axis Mode	360 ° (Z rotation)		Single axis rotation angle measurement value while Z axis (vector normal to circuit board is within $\pm 45^{\circ}$ of horizontal.*		surement valid circuit board)	
			Angle range			
Tunical angular drift due to tomporature			± 10 °	± 45 °	± 70 ° **	360 ° (single axis)
Values represent 1 sigma confidence in tilt mode.	<u>perature</u> range	15 C to +35 C	$\pm \ 0.06$ °	± 0.06 °	± 0.3 °	± 0.1 °
		0 C to +70 C	± 0.3 °	± 0.3 °	± 1.6 °	± 0.6 °
	Ten	-40 C to +85 C	$\pm \ 0.4$ °	\pm 0.4 °	± 1.7 °	± 0.8 °

* Note: Angle ranges measured with respect to deviations from horizontal.

**** Note:** Useable up to +/- 80 ° with degraded accuracy.

RANGE & TEMPERATURE PERFORMANCE (SQ-RIW)

Based on SignalQuest inclinometer model SQ-SI2X-360DA

PARAMETER	SPECIFICATION		Notes		
Angle range - Tilt Mode	360 ° x 180 °	(X tilt, Y tilt)	Dual axis tilt ranges		
Angle range - Gimbaled Mode	360 ° x 90 ° (Y rotation, Y tilt)		360 ° x 90 ° (Y rotation, Y tilt)Y rotation valid while Y tilt is within ± 45 ° of horizontal.***		
			Angle range		
Tunical angular drift due to temperature			\pm 10 ° from any axis	± 45 ° from any axis (max error)	
Values represent 1 sigma confidence in tilt mode.	ture	15 C to +35 C	± 0.06 °	± 0.1 °	
	<u>iperat</u> range	0 C to +70 C	± 0.3 °	± 0.6 °	
	Ten	-40 C to +85 C	± 0.4 °	± 0.8 °	

*****Note:** Angle ranges measured with respect to deviations from inertial X,Y, Z reference frame.

DAMPING OPTIONS (F & S)

After warm-up, the sensor continuously streams data on the CAN bus at the Update Rate.

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SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

Parameter	F Option	S Option	Notes
Warm up time from power on	0.2 s	1.0 s	Angle jitter and vibration are digitally filtered
Measurement settling time	0.1 s	0.5 s	Angle jitter and vibration are digitally intered
Update Rate	40 Hz		Update rate is factory configurable – contact SignalQuest for other options

PIN CONFIGURATION

SINGLE CONNECTOR MODELS & PRIMARY CONNECTOR ON DUAL CONNECTOR MODELS

Pin	Signal Name	Usage
1	SWCLK	Factory Programming Interface
2	ADDR_0	Address I/0 Line
3	V+	Voltage Supply
4	GND	Ground
5	C2CK	Factory Programming Interface
6	C2D	Factory Programming Interface
7	SWDIO	Factory Programming Interface
8	CAN_L	CAN Bus L Signal
9	CAN_H	CAN Bus H Signal
10	CAN_SHLD	CAN Shield
11	RST	Factory Programming Interface
12	ADDR_1	Address I/O Line

*Note: Grey boxes indicate that a signal is available only on a custom application basis.

SECONDARY CONNECTOR ON DUAL CONNECTOR MODELS

Pin	Signal Name	Usage
1	IO A	Reserved I/O
2	IO_B	Reserved I/O
3	GND	Ground
4	V+	Voltage Supply
5	IO_C	Reserved I/O
6	C2CK	Factory Programming Interface
7	IO_D	Reserved I/O
8	IO_E	Reserved I/O
9	CAN_SHLD	CAN Shield
10	CAN_H	CAN Bus H Signal
11	CAN_L	CAN Bus L Signal
12	C2D	Factory Programming Interface

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SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

ADDRESSING

Device IDs can be factory set or specified using the ADDR_0 and ADDR_1 lines on the primary connector.

When addressing is specified by the ADDR_0 and ADDR_1 lines the default (open) state is logic '1'. Connect ADDR_0 and ADDR_1 to ground as appropriate to specify the device address. Device functionality is as follows:

RIL Model:

Device ID	ADDR_1:ADDR_0	Mode	Address	Priority
0	0:0	Single-Axis	0xA2	0
1	0:1	Single-Axis	0xA3	1
2	1:0	Single-Axis	0xA4	2
3	1:1	Dual-Axis	0xA5	3

RIW Model:

Device ID	ADDR_1:ADDR_0	Mode	Address	Priority
0	0:0	Tilt	0xA2	0
1	0:1	Tilt	0xA3	1
2	1:0	Tilt	0xA4	2
3	1:1	Gimballed	0xA5	3

CAN PACKET DATA FORMAT: DUAL-AXIS (RIL), TILT/GIMBALLED MODE (RIW)

PARAMETER DEFINITIONS

P1:

Parameter	Width (bits)	Туре	Min Value	Max Value	Units
YTilt	16	Unsigned Integer	0	3599	0.1 degrees
XTilt	16	Unsigned Integer	0	1800	0.1 degrees
Status	8	Bit Vector	0x00	0xFF	n/a

* NOTE: Divide the integer Y Tilt and X Tilt values by 10 to compute the angle in units of degrees.

P2:

Parameter	Width (bits)	Туре	Min Value	Max Value	Units
YTilt	16	Unsigned Integer	0	35999	0.01 degrees
XTilt	16	Unsigned Integer	0	18000	0.01 degrees
Status	8	Bit Vector	0x00	0xFF	n/a

* NOTE: Divide the integer Y Tilt and X Tilt values by 100 to compute the angle in units of degrees.

DATA FIELD PAYLOAD (5 BYTES)

1	2	3	4	5
YTiltLow	YTiltHigh	XTiltLow	XTiltHigh	Status

Data Field Payload Descriptions

Parameter	Payload	Meaning
vm;l+	YTiltLow	Low byte of 16 bit YTilt value
IIIL	YTiltHigh	High byte of 16 bit YTilt value
XTilt	XTiltLow	Low byte of 16 bit XTilt value
	XTiltHigh	High byte of 16 bit XTilt value
Status	Status	Status Bit Vector (see table below)

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SQ-RI SERIES

The Status bit vector flags the following conditions – note that Status = 0 indicates normal operation:

Bit Vector Position	Flag	Meaning
0 (LSB)	0x01	Sensor Warming Up
4	0x10	Sensor Synchronization Lost
6	0x40	Device ID changed after power-on – possible wiring fault
7	0x80	Firmware fault – device restarted by internal watchdog monitor

CAN PACKET DATA FORMAT: SINGLE-AXIS

PARAMETER DEFINITIONS

P1:

Parameter	Width (bits)	Туре	Min Value	Max Value*	Units
ZRotation	16	Unsigned Integer	0	3599	0.1 degrees
ZTilt	16	Unsigned Integer	0	1800	0.1 degrees
Status	8	Bit Vector	0x00	0xFF	n/a

* NOTE: Divide the integer Y Tilt and X Tilt values by 10 to compute the angle in units of degrees.

P2:

Parameter	Width (bits)	Туре	Min Value	Max Value*	Units
ZRotation	16	Unsigned Integer	0	35999	0.01 degrees
ZTilt	16	Unsigned Integer	0	18000	0.01 degrees
Status	8	Bit Vector	0x00	0xFF	n/a

* NOTE: Divide the integer Y Tilt and X Tilt values by 100 to compute the angle in units of degrees.

DATA FIELD PAYLOAD (5 BYTES)

1	2	3	4	5
ZRotationLow	ZRotationHigh	ZTiltLow	ZTiltHigh	Status

Data Field Payload Descriptions

Parameter	Payload	Meaning
	ZRotationLow	Low byte of 16 bit Rotation value
ZRotation	ZRotation	High byte of 16 bit Rotation value
	High	
7 መ ነ 1 +	ZTiltLow	Low byte of 16 bit Tilt value
2111L	ZTiltHigh	High byte of 16 bit Tilt value
Status	Status	Status Bit Vector (see table below)

The Status bit vector flags the following conditions – note that Status = 0 indicates normal operation:

Bit Vector Position	Flag	Meaning
0 (LSB)	0x01	Sensor Warming Up
4	0x10	Sensor Synchronization Lost
6	0x40	Device ID changed after power-on – possible wiring fault
7	0x80	Firmware fault – device restarted by internal watchdog monitor

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SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

ORIENTATION

TERMINOLOGY

Gravity means a vector pointing from the device toward the center of the earth. X means a vector parallel to the "X" arrow printed on housing label Y means a vector parallel to the "Y" arrow printed on the housing label Z means a vector passing through "Z" arrow printed on the housing label Horizontal means the arrow is pointing at a right angle to gravity. Straight Down means the arrow is parallel to gravity. Straight Up means that the arrow is anti-parallel to gravity (i.e. pointing toward the sky). Plumb Line is a line with a weight on the end hanging straight down.

SQ-RIL MODEL

DUAL -AXIS MODE

In Dual-Axis Mode the X Tilt and Y Tilt angles are measured between gravity and the arrows printed on the housing label. If you passed a Plumb Line through the sensor's X, Y, Z origin, the X and Y Tilt angles could be measured by placing a protractor's straight edge on the plum line and then reading the angles made with each arrow.

Y Tilt = Pitch (first angle) X Tilt = Roll (second angle)

Holding Y Horizontal

When X is Horizontal, X Tilt = 90 °. When X is Straight Up, X Tilt = \sim 180 °. When X is Straight Down, X Tilt = \sim 0 °.

Holding X Horizontal

When Y is Horizontal, Y Tilt = 90 °. When Y is Straight Up, Y Tilt = \sim 180 °. When Y is Straight Down, Y Tilt = \sim 0 °.

SINGLE -AXIS MODE

In Single-Axis Mode, the Z Rotation angle is defined as a rotation *about* the Z axis of the sensor. For the Z Axis Rotation angle to remain in range, the Z Axis must be near horizontal. The Z axis should be kept to less than ± 45 ° of deviation from horizontal. Pitch angle values are factory calibrated to within +/- 0.1° alignment with the sensor enclosure

When X is Horizontal, Y is Straight Up, Z Rotation = $0/360^{\circ}$. When Y is Horizontal, X is Straight Down, Z Rotation = 90° . When X is Horizontal, Y is Straight Down, Z Rotation = 180° . When Y is Horizontal, X is Straight Up, Z Rotation = 270° .

IMPORTANT NOTES

• Regardless of the mode, the inclinometer measures angles with respect to gravity. It <u>cannot</u> measure rotation about the gravity vector. All rotations about gravity are *invisible* to the sensor and are considered equivalent.

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SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

SQ-RIW MODEL

TILT MODE

In Tilt Mode the X Tilt and Y Tilt angles are measured between gravity and the white silkscreen arrows printed on the main circuit board. If you passed a Plumb Line through the inclinometer's X, Y, Z origin, the X and Y Tilt angles could be measured by placing a protractor's straight edge on the plum line and then reading the angles made with each arrow.

Y Tilt = Pitch (first angle) X Tilt = Roll (second angle)

Holding Y Horizontal

When X is Horizontal and Z is <u>Straight Up</u>, X Tilt = 90 °. When X is Horizontal and Z is <u>Straight Down</u>, X Tilt = 270 °. When X is Straight Up, X Tilt = 180 °. When X is Straight Down, X Tilt = 0/360 °.

Holding X Horizontal

When Y is Horizontal, Y Tilt = 90 °. When Y is Straight Up, Y Tilt = 0 °. When Y is Straight Down, Y Tilt = 180 °.

GIMBALED MODE

In both Tilt Mode and Gimbaled Mode, the Y Tilt measurement is identical. However, in Gimbaled Mode, the Y Rotation angle is defined as a rotation *about* the Y axis of the device. You will find that this is similar to X Tilt (in Tilt Mode) when near horizontal, but further from horizontal, the difference between these two measurement methods is quite pronounced.

For users familiar with Euler Angles, this measurement mode is equivalent to performing the Euler X-Y transformation on the Tilt Mode coordinates, and then adjusting the quadrants to be continuous. In Gimbaled Mode unlike Tilt Mode, there will be no numerical discontinuities near 0 and 180 degrees for X Tilt, when Y is not Horizontal.

IMPORTANT NOTES

- Tilt Mode angles are <u>not</u> generally equivalent to Gimbaled Mode angles. Tilting X up or down in the Tilt Mode coordinate system is <u>not</u> equivalent to making a rotation about the Y axis unless Y is fixed horizontally. The same is true for the X axis. Consult SignalQuest technical support and reference material on orientation reference frames.
- Users wanting to measure rotations about the inclinometer's Y axes rather than tilt angle with respect to gravity, should use the Gimbaled Mode coordinate system. To convert a dataset from Tilt Mode coordinates (the sensor's native output) to Gimbaled Mode coordinates, contact SignalQuest for application notes and sample software.
- Regardless of the coordinate frame used the inclinometer measures angles with respect to gravity. It <u>cannot</u> measure rotation about the gravity vector. All rotations about gravity are *invisible* to the sensor and are considered equivalent.

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SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

PACKAGING

SINGLE CONNECTOR MODELS (-1C, -1CA)

The SQ-RPI sensor uses a Deutsch DTF13-12PA (DTF Series 12 Way Receptacle 90° Flangeless Key Arrangement A) for the primary connector.





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SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

DUAL CONNECTOR MODELS (-2C, -2CA)

The SQ-RPI sensor uses a Deutsch DTF13-12PA (DTF Series 12 Way Receptacle 90° Flangeless Key Arrangement A) for the primary connector. The dual connector models use a Deutsch DTF13-12PB (DTF Series 12 Way Receptacle 90° Flangeless Key Arrangement B) for the secondary connector.





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SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

SMALL PACKAGE FLYING LEAD (-3C)

- 1. IP65 protection rating
- 2. Flying lead, small form factor
- 3. 8 conductor, flying lead
- 4. Only tap bus topology support at this time.

Pin	Signal Name	Color	Usage
1	Factory 1		
2	Factory 2		Factory Programming Interface
3	Factory 3		
4	V+		Voltage Supply
5	GND		Ground
6	CAN_L		CAN Bus L Signal
7	CAN_H		CAN Bus H Signal
8	CAN_SHLD		CAN Shield





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SQ-RI SERIES

RUGGED PACKAGED INCLINOMETER, CAN2.0B/J1939

ORDERING OPTIONS

OPTIONS	CODE	Option	NOTES					
del	SQ-RIL	Dual-Axis: \pm 70 ° dual Single-Axis: 360 °	Low range					
W	SQ-RIW	Dual-Axis: 360° x 180°	Wide range	Wide range				
er ator on	-12R	5 – 15 V supply						
Pow regult opti	-36R	7 – 36 V supply	Standard version (stock)					
		CONNECTOR TYPE	PACKAGE TYPE	PROTECTION RATING	BUS TOPOLOGY	NOTES		
	-1C	1 Deutsch, 12 pin	SQ-ENCL-8	IP67	Tap bus (internal CAN terminator)			
	-1CA	1 Deutsch, 12 pin, black anodized	SQ-ENCL-8	IP67	Tap bus (internal CAN terminator)			
	-2C	2 Deutsch, 12 pin	SQ-ENCL-7	IP67	In-line bus			
option	-2CA	2Deutsch, 12 pin, black anodized	SQ-ENCL-7	IP67	In-line bus			
ckage	-3C	Flying lead	SQ-ENCL-3	IP65	Tap bus (internal CAN terminator)			
Pac	-4C	1 circular connector	SQ-ENCL-9	IP68	Tap bus (internal CAN terminator)			
	-5C	2 circular connectors	SQ-ENCL-10	IP68	In-line bus			
	-7C	1 connector, low cost	SQ-ENCL-11	IP67	Tap bus (internal CAN terminator)			
	-8C	2 connector, low cost	SQ-ENCL-11	IP67	In-line bus			
nance on	-P1	Standard performance	Standard accuracy and resolution					
Perforr opti	-P2	High performance	Higher accuracy and resolution					
ping option	-S	500 mS settling time	Better noise rejection, slower response time – This model uses a 0.5 second moving average filter to provide digital damping. This reduces the impact that spurious accelerations and vibrations have on the angle reading. This model will reject noise better than the "F" model, but with the tradeoff of a slower response time.					
Dam	-F	100 mS settling time	Faster response time, poorer noise rejection – This model uses a 0.1 second moving average filter to provide digital damping. This model will respond more quickly to changes in angle than the "S" model but with the trade off of poorer noise rejection					
	ID0	ID0 (Address 0xA2)						
ŋg	ID1	ID1 (Address 0xA3)						
ion	ID2	ID2 (Address 0xA4)						
ldre	ID3	ID3 (Address 0xA5)						
, PA	IDX	Hardware Addressable						
	IDS	Software Addressable	Coming soon					

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Other option	-Custom	Customer-specific requirements	Please contact SignalQuest if you require an option not listed in this table. For example, various baud rates, setting times, update rates and voltage regulator options may be available on request.
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All SQ-RI devices are based on the SQ-SI or SI2X base inclinometer. For more information about inclinometer specifications not listed here, please refer to <u>http://www.signalquest.com/sq-si.htm</u>

Example part numbers: SQ-RIL-12R-1C-P1-S-IDX

LIMITATIONS AND WARNINGS

LIFE SAFETY

This product is not designed for use in life support and/or safety equipment where malfunction of the product can reasonably be expected to result in personal injury or death. Buyer uses this product in such applications at Buyer's own risk and agrees to defend, indemnify, and hold harmless SignalQuest, LLC from any and all damages, claims, suits, or expenses resulting from such misuse.

DYNAMIC ENVIRONMENTS

The device is designed to be used to measure angles in a quasi-static environment where external vibrations and accelerations are kept to a minimum. Digital and analog signal processing methods are employed to reduce the effects of transient acceleration and small vibrations on the angle reading; however, under dynamic conditions where external accelerations or vibrations are present, the sensor's performance may be degraded.

VARIATIONS IN EARTH'S GRAVITY

This device is designed to be used near the earth's surface only. Substantial changes in gravity will degrade the performance of the sensor. This device is not intended or qualified to be used in aviation.

TESTING

The performance of each system is verified through build-time testing. Each system is tested before and after factory calibration to ensure reliable performance.

SYSTEM INTEGRATION TESTING

Thorough testing should be carried out prior to product release to ensure system integration has not introduced unforeseen problems. The system integrator assumes the ultimate responsibility for the safety of the target application.

NOTICE

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FURTHER INFORMATION

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8xx Series

8xxB Series

FUNCTION

- On / off tilt sensing
- Non-sensitive to vibration when open
- Normally open when horizontal
- Normally closed when below the switch angle

APPLICATIONS

- Security, anti-tamper, anti-theft, alarms
- TV remote control tilt wake-up
- Screen orientation

DESCRIPTION

The SQ-SEN-8xx sensor acts like a position sensitive switch that is normally open when horizontal, and normally closed below the switch angle. It is designed to be non-sensitive to vibration a horizontal orientation. When at rest in a horizontal orientation, the sensor will settle in an open state. When tipped down from vertical to the "switch angle" it will produce continuous on/off contact closures while in motion. When at rest below the switch angle, it will settle normally open.

PATENTS

United States: 7421793, Taiwan: I331674. Patents pending.

DATASHEET

SQ-SEN-8XX

ON/OFF TILT SENSOR, HORIZONTAL NORMALLY OPEN

FEATURES

- **Zero-power Normally -** < 50 nA when activated
- High Sensitivity & Long Life Semiconductor grade electroplating
- Miniature Size 3.3 mm x 6.9 mm
- Simple Interface No signal conditioning required
- **Quiet** Undetectable sound level
- Surface Mount- RoHS compliant, lead-free, tape and reel
- Activation Angle Available in 15°, 30°, 45°, 15° Bi-directional
- Made in USA fully automated production, 100% testing, worldwide quality and price leader

FUNCTIONAL DIAGRAM

8XX SERIES SINGLE SIDED

SQ-SEN-815, SQ-SEN-830, SQ-SEN-845



8xx Series Bidirectional SQ-SEN-815B







ON/OFF TILT SENSOR, HORIZONTAL NORMALLY OPEN

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SQ-SEN-8xx

ON/OFF TILT SENSOR, HORIZONTAL NORMALLY OPEN

THEORY OF OPERATION

The SQ-SEN-8xx sensor acts like a position sensitive switch which is normally open in a range of orientations, and normally closed in another range of orientations. When resting in a normally open orientation, contacts are virtually guaranteed to be open. When resting in the normally closed orientation (unlike normally open) contacts are <u>not guaranteed to be closed</u>. A good rule of thumb is that they will be closed 95% - 99% of the time, when at rest.

When in a normally closed orientation, the sensor will chatter open and closed as it is vibrated. The engineer should design his or her software to look for high-to-low and low-to-high edge transitions rather than an open or closed state of the switch.

FUNCTIONAL BEHAVIOR

PART	SWITCH CLOSED ANGLE Degrees down from horizontal	SWITCH OPEN ANGLE Degrees back to horizontal
SQ-SEN-815	15	2
SQ-SEN-815B	+15, -15	2+, -2
SQ-SEN-830	27	9
SQ-SEN-845	37	17

Data represents average values.

CHARACTERISTICS

PARAMETER	MIN	Мах	CONDITIONS
Shock Survival		5,000 g	5x, 0.1 ms half-sin, any axis
Storage Temperature	-40° C	85° C	
Supply Voltage Range	0.5 V	12 V	
Current Sink*	50 nA	10 mA	

* Current consumption is determined by the resistance of the application circuit and the supply voltage.

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SQ-SEN-8XX

ON/OFF TILT SENSOR, HORIZONTAL NORMALLY OPEN

DIMENSIONS 8XX



Symbol	DESCRIPTION	ММ	TOLERANCE
А	Length	6.8	±0.25
В	Diameter	3.3	±0.1
С	Terminal Width 1	0.8	±0.25
D	Solder Nub Diameter	0.9	±0.25
Е	Solder Nub Length	0.4	±0.1
F	Terminal Width 2	0.4	±0.25

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SQ-SEN-8XX

ON/OFF TILT SENSOR, HORIZONTAL NORMALLY OPEN

DIMENSIONS 8XXB



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ON/OFF TILT SENSOR, HORIZONTAL NORMALLY OPEN

EXAMPLE PCB LANDING

RECOMMEN	IDED PCB LANDING		ALTERNATE, PCB CUTOUT LANDING (USE FOR LOV	VEST PROFILE)	
Symbol	DESCRIPTION	ММ		Symbol	DESCRIPTION	ММ
А	Pitch	6.0		А	Recess Length	7.25
В	Pad Length	1.2		В	Pad Length	0.8
С	Pad Width	2.1		С	Pad Width	1.5
	1			D	Recess Width	3.6
	A		B A	ers as necessary -		

*Note: Alternative layouts may be used to optimize size or manufacturability

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SQ-SEN-8xx

ON/OFF TILT SENSOR, HORIZONTAL NORMALLY OPEN

PRODUCT COMPARISON

GRADE	Assembly Method	SEALED	WASHABLE	RoHS	Operating Temperature	CYCLES *	SERVICE Life (YRS)
Ι	Reflow Solder: 260° C peak Hand Assembly: 315° C peak, 2 -3 seconds on end terminal	Yes	Yes	Yes	-40° to +85° C	1 Billion	10
С	Reflow Solder: 260° C peak Hand Assembly: 315° C peak, 2 -3 seconds on end terminal	Yes	Yes	Yes	-25° to +70° C	1 Billion	5

*Test conditions: 0.5 gRMS, 5 to 200 Hz flat spectrum

Ordering Guide

PART NUMBER	PACKAGING CODE	EXAMPLE COMPLETE PART NUMBER
SQ-SEN-815-C SQ-SEN-815B-C SQ-SEN-830-C SQ-SEN-845-C	TR - Tape on Reel	SQ-SEN-815-CTR
SQ-SEN-815-I SQ-SEN-815B-I SQ-SEN-830-I SQ-SEN-845-I	CT - Cut Tape TR - Tape on Reel	SQ-SEN-815-ITR

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SQ-SEN-8XX

ON/OFF TILT SENSOR, HORIZONTAL NORMALLY OPEN

LIMITATIONS AND WARNINGS

This product is not designed for use in life support and/or safety equipment where malfunction of the product can reasonably be expected to result in personal injury or death. Buyer uses this product in such applications at Buyer's own risk and agrees to defend, indemnify, and hold harmless SignalQuest, LLC from any and all damages, claims, suits, or expenses resulting from such misuse.

TESTING

The performance of each sensor is verified through build-time testing.

SYSTEM INTEGRATION TESTING

Thorough testing should be carried out prior to product release to ensure system integration has not introduced unforeseen problems. The system integrator assumes the ultimate responsibility for the safety of the target application.

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NOTES

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SQ-SEN-200

NANO-POWER TILT AND VIBRATION SENSOR



FUNCTION

- Normally closed at rest
- Omnidirectional movement sensing
- Chatters open / closed when tilted or vibrated in any direction regardless of orientation

APPLICATIONS

- Motion triggered wake-up
- GPS tracking, RFID, vehicle electronics
- Security, anti-tamper, anti-theft, alarms

DESCRIPTION

The SQ-SEN-200 series sensor acts like a normally closed switch which chatters open and closed as it is tilted or vibrated. Unlike other rolling-ball sensors, the 200 is truly an omnidirectional movement sensor. It will function regardless of how it is mounted or aligned.

When at rest, it normally settles in a closed state. When in motion, it will produce continuous on/off contact closures. It is sensitive to both tilt (static acceleration) and vibration (dynamic acceleration). The sensor can be easily used to produce a series of CMOS or TTL level logic level or pulse train using a single resistor to limit current. The signal level can be read directly by a digital input. This can be used to interrupt (wake up) a microcontroller or can be counted to estimate the amount and duration of activity. The sensor is fully passive, requires no signal conditioning, and draws as little as 50 nA of continuous current.

PATENTS

United States: 7326866, 7067748, 7326867, Taiwan: I334019, Korea: 10-0946453, Mexico: 275272. Patents pending.

FEATURES

- Miniature Size 3.3 mm x 6.8 mm
- **Simple Interface -** No signal conditioning required
- Surface Mount RoHS & REACH compliant, lead free, Halogen free
- Made in USA Fully automated production, 100% testing, worldwide quality and price leader
- Nano-power As little as 50 nA
- Industrial Rated 10 year life, -40° to 85° C

FUNCTIONAL DIAGRAM







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SQ-SEN-200

NANO-POWER TILT AND VIBRATION SENSOR

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SQ-SEN-200

NANO-POWER TILT AND VIBRATION SENSOR

THEORY OF OPERATION

The SQ-SEN-200 series sensor acts like a normally closed switch which chatters open and closed as it is tilted or vibrated. Note that the SQ-SEN-200 is <u>not guaranteed to be closed</u> – occasionally the sensing mechanism may remain open when at rest. The engineer should design his or her software to look for high-to-low and low-to-high edge transitions rather than an open or closed state of the switch.

CHARACTERISTICS

PARAMETER	MIN	Мах	CONDITIONS
Shock Survival		5,000 g	5x, 0.1 ms half-sin, any axis
Storage Temperature	-40° C	85° C	
Supply Voltage Range	0.5 V	12 V	
Current Sink*	50 nA	10 mA	

* Current consumption is determined by the resistance of the application circuit and the supply voltage.

DIMENSIONS



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SQ-SEN-200

NANO-POWER TILT AND VIBRATION SENSOR

EXAMPLE PCB LANDING

RECOMMENDED PCB LANDING		ALTERNATE, PCB CUTOUT LANDING (USE FOR LOV	VEST PROFILE)		
Symbol	DESCRIPTION	ММ		Symbol	DESCRIPTION	ММ
А	Pitch	6.0		А	Recess Length	7.25
В	Pad Length	1.2		В	Pad Length	0.8
С	Pad Width	2.1		С	Pad Width	1.5
L				D	Recess Width	3.6
C C B			B A	ers as necessary -		

*Note: Alternative layouts may be used to optimize size or manufacturability

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SQ-SEN-200

NANO-POWER TILT AND VIBRATION SENSOR

PRODUCT COMPARISON

GRADE	Assembly Method	SEALED	WASHABLE	RoHS	Operating Temperature	CYCLES *	SERVICE Life (YRS)
Ι	Reflow Solder: 260° C peak Hand Assembly: 315° C peak, 2 -3 seconds on end terminal	Yes	Yes	Yes	-40° to +85° C	1 Billion	10
С	Reflow Solder: 260° C peak Hand Assembly: 315° C peak, 2 -3 seconds on end terminal	Yes	Yes	Yes	-25° to +70° C	1 Billion	5

ORDERING GUIDE

PART NUMBER	PACKAGING CODE	COMPLETE ORDER NUMBER
SQ-SEN-200-C	TR - Tape on Reel	SQ-SEN-200-CTR
SQ-SEN-200-I	CT - Cut Tape TR - Tape on Reel	SQ-SEN-200-ICT SQ-SEN-200-ITR

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SQ-SEN-200

NANO-POWER TILT AND VIBRATION SENSOR

LIMITATIONS AND WARNINGS

This product is not designed for use in life support and/or safety equipment where malfunction of the product can reasonably be expected to result in personal injury or death. Buyer uses this product in such applications at Buyer's own risk and agrees to defend, indemnify, and hold harmless SignalQuest, LLC. from any and all damages, claims, suits, or expenses resulting from such misuse.

TESTING

The performance of each sensor is verified through build-time testing.

SYSTEM INTEGRATION TESTING

Thorough testing should be carried out prior to product release to ensure system integration has not introduced unforeseen problems. The system integrator assumes the ultimate responsibility for the safety of the target application.

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SQ-SEN-390

ON/OFF TILT SENSOR



FUNCTION

- Normally closed when below horizontal
- Non-sensitive to vibration when open
- On/off tilt sensing
- Normally open when above horizontal

APPLICATIONS

Security, anti-tamper, anti-theft, alarms

DESCRIPTION

The SQ-SEN-390 series sensor acts like a position sensitive switch which is normally closed when below horizontal and normally open when above horizontal.

When at rest, it normally settles in a closed state. When in motion, it will produce continuous on/off contact closures. It is sensitive to both tilt (static acceleration) and vibration (dynamic acceleration). The sensor can be easily used to produce a series of CMOS or TTL level logic level or pulse train using a single resistor to limit current. The signal level can be read directly by a digital input. This can be used to interrupt (wake up) a microcontroller or can be counted to estimate the amount and duration of activity. The sensor is fully passive, requires no signal conditioning, and draws as little as 50 nA of continuous current.

PATENTS

United States: 7421793, Taiwan: I331674. Patents pending.

FEATURES

- Simple Interface No signal conditioning required
- Surface Mount RoHS & REACH compliant, lead free, Halogen free
- Made in USA fully automated production, 100% testing, worldwide quality and price leader
- Zero-power Normally <50 nA when activated
- Activation Angle 90°
- Industrial Rated 10 year life, -40° to 85° C
- Miniature Size 3.3 mm x 6.9 mm

FUNCTIONAL DIAGRAM





SQ-SEN-390

ON/OFF TILT SENSOR

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SQ-SEN-390

ON/OFF TILT SENSOR

THEORY OF OPERATION

The SQ-SEN-3XX series sensor acts like a position sensitive switch which is normally open in a range of orientations, and normally closed in another range of orientations. When resting in a normally open orientation, contacts are virtually guaranteed to be open. When resting in the normally closed orientation (unlike normally open) contacts are <u>not guaranteed to be closed</u>. A good rule of thumb is that they will be closed 95% - 99% of the time, when at rest.

When in a normally closed orientation, the sensor will chatter open and closed as it is vibrated. The engineer should design his or her software to look for high-to-low and low-to-high edge transitions rather than an open of closed state of the switch.

CHARACTERISTICS

PARAMETER	MIN	Мах	CONDITIONS
Shock Survival		5,000 g	5x, 0.1 ms half-sin, any axis
Storage Temperature	-40 °C	85 °C	
Supply Voltage Range	0.5 V	12 V	
Current Sink*	50 nA	10 mA	

* Current consumption is determined by the resistance of the application circuit and the supply voltage.

DIMENSIONS



Symbol	DESCRIPTION	ММ	TOLERANCE
А	Length	6.8	±0.25
В	Diameter	3.3	±0.1
С	Terminal Width	0.8	±0.25
D	Solder Nub Diameter	0.9	±0.25
Е	Solder Nub Length	0.4	±0.1
F	Terminal Width 2	0.4	±0.25

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SQ-SEN-390

ON/OFF TILT SENSOR

EXAMPLE PCB LANDING

RECOMMENDED PCB LANDING			ALTERNATE, PCB CUTOUT LANDING (USE FOR LOV	WEST PROFILE)	
Symbol	DESCRIPTION	ММ		Symbol	DESCRIPTION	ММ
А	Pitch	6.0		А	Recess Length	7.25
В	Pad Length	1.2		В	Pad Length	0.8
С	Pad Width	2.1		С	Pad Width	1.5
	1	1		D	Recess Width	3.6
	A		B C C C C C C C C C C C C C C C C C C C	ers as necessary -		

*Note: Alternative layouts may be used to optimize size or manufacturability

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SQ-SEN-390

ON/OFF TILT SENSOR

PRODUCT COMPARISON

GRADE	Assembly Method	SEALED	WASHABLE	RoHS	Operating Temperature	CYCLES *	SERVICE Life (YRS)
Ι	Reflow Solder: 260° C peak Hand Assembly: 315° C peak, 2 -3 seconds on end terminal	Yes	Yes	Yes	-40° to +85° C	1 Billion	10
С	Reflow Solder: 260° C peak Hand Assembly: 315° C peak, 2 -3 seconds on end terminal	Yes	Yes	Yes	-25° to +70° C	1 Billion	5

*Test conditions: 0.5 gRMS, 5 to 200 Hz flat spectrum

ORDERING GUIDE

PART NUMBER	PACKAGING CODE	Complete Order Number
SQ-SEN-390-C	TR - Tape on Reel	SQ-SEN-390-CTR
SQ-SEN-390-I	CT - Cut Tape TR - Tape on Reel	SQ-SEN-390-ICT SQ-SEN-390-ITR

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SQ-SEN-390

ON/OFF TILT SENSOR

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TESTING

The performance of each sensor is verified through build-time testing.

SYSTEM INTEGRATION TESTING

Thorough testing should be carried out prior to product release to ensure system integration has not introduced unforeseen problems. The system integrator assumes the ultimate responsibility for the safety of the target application.

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SQ-SI2X-360DA

SOLID-STATE WIDE RANGE MEMS INCLINOMETER

 $360\ensuremath{\,^\circ}\x180\ensuremath{\,^\circ}\x180$ output axis, serial and analog output

SQ-SI2X-360DA-HMP

FUNCTION

- Wide range 360 ° x 180 ° dual axis angle measurement
- UART serial output and analog output

APPLICATIONS

- Platform and vehicle leveling
- Satellite dish and antenna alignment
- Machine control and monitoring
- Angle measurement and recording

• Computer input, head tracking, and mouse pointing

DESCRIPTION

The inclinometer module performs calibrated angle measurement with analog voltage and digital serial outputs.

FEATURES

- 0.1 ° resolution digital serial output
- Low temperature drift
- Factory calibrated angle output
- High reliability solid-state MEMS
- Digital filtering for stable measurement
- Direct PC interface cable

THEORY OF OPERATION

The inclinometer uses three factory calibrated accelerometers to measure and compute angles made between its axes and the gravity vector. The trigonometric conversions between acceleration and angle are made by an onboard processor. Digital filtering reduces the impact of spurious acceleration and vibration on the reported angle.

FUNCTIONAL DIAGRAM



EXAMPLE ANALOG OUTPUT

The graph below shows an example of the analog output from a device in single axis mode. The device is rotated 720° clockwise from a 0° starting position at a rate of 180°/sec. The output is linear with a piecewise overflow at 360°. The second axis output is similar, but each axis reaches a maximum at 180° and descends back to 0° rather than overflowing. U8

Angle vs. Output Voltage



RANGE AND SCALE

PARAMETER	UNITS	VALUE
Scale Factor	V/deg	$0.0022 \times V_{cc}$
Offset (0° value)	V	$0.100 \times V_{cc}$
Max (359° value)	V	$0.895 \times V_{cc}$

 $Output(V) = Offset(V) + ScaleFactor(V/deg) \times Angle(deg)$

$$Angle(deg) = \frac{Output(V) - Offset(V)}{ScaleFactor(V/deg)}$$

Updated: 2014-01-16



SQ-SI2X-360DA

SOLID-STATE WIDE RANGE MEMS INCLINOMETER

 $360\,^{\rm o}$ x $180\,^{\rm o}$ dual axis, serial and analog output

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SQ-SI2X-360DA

SOLID-STATE WIDE RANGE MEMS INCLINOMETER

360 ° x 180 ° DUAL AXIS, SERIAL AND ANALOG OUTPUT

ABSOLUTE MAXIMUM RATINGS

PARAMETER	Min	TYPICAL	Мах	NOTES
Voltage on $+V_{cc}$ - without regulator - NR option	-		4.2 V	With respect to GND
Voltage on $+V_{cc}$ - with regulator - R option	-		5.8 V	with respect to GND
Voltage on any input pin			5.8 V	With respect to GND
Peak-to-peak supply noise - without regulator -NR option			50 mV	
Peak-to-peak supply noise - with regulator - R option			200 mV	
Operating temperature	-40 °C		85 °C	
Shock survivability			$500 g_n$	Where 1 g_n is assumed to be = 9.81 m/s ²
Operating vibration			$0.25 g_n$	

Note: Exposure to conditions outside of the Absolute Maximum Ratings may damage the device. Prolonged exposure to conditions at the Absolute Maximum Ratings may result in degraded performance of the device over time.

ELECTRICAL CHARACTERISTICS

[Test conditions: 3.3v regulator, 25 °C unless otherwise specified]

PARAMETER	Min	TYPICAL	MAX	NOTES
Supply voltage - without regulator - NR option	2.9 V		3.5 V	With respect to GND
Supply voltage - with 3.0 volt regulator - 3.0R option	3.2 V		5.8 V	12 V versions also
Supply voltage - with 3.3 volt regulator - 3.3R option	3.5 V		5.8 V	factory.
Supply current - HP option		5.4 mA		
Supply current - LP option		2.4 mA		
Supply current - ULP option	0.5 μΑ	57 μΑ	2.4 mA	Operating at 1 sample per second, no filtering, no oversampling
Output voltage*	0.3 V		$0.9 \times V_{cc}$	
Sensitivity*		0.0022 × V _{cc} / °		See note below regarding V _{cc}
Full-scale output range*	$0.100 \times V_{cc}$		$0.895 \times V_{cc}$	
Analog output current			20 µA	
Input voltage High	2.0 V			
Input voltage Low			0.8 V	
Output voltage High	$0.\overline{895 \times V_{cc}}$		V _{cc}	
Output voltage Low	0 V		$0.100 \times V_{cc}$	

*Note: For the NR model (without onboard regulator), V_{cc} is the voltage supplied to the device. For the 3.0R and 3.3R models (3.0 V or 3.3 V onboard regulators), V_{cc} is 3.0 V or 3.3 V respectively. If your application requires using a 12 V supply, consult the factory for 12 V models.

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SQ-SI2X-360DA

SOLID-STATE WIDE RANGE MEMS INCLINOMETER

 $360\,^{\rm o}$ x $180\,^{\rm o}$ dual axis, serial and analog output

PERFORMANCE PARAMETERS

[Test conditions: 3.3v regulator, 25 ° C unless otherwise specified]

PARAMETER	SPECIFICATION		Notes	
Angle accuracy (differential) - HP option	± 1 °		From one on allo to one other on allo within	
Angle accuracy (differential) - LP option	± 2 °		From any angle to any other angle within	
Angle accuracy (differential) - ULP option	±2°		Tallge	
Angle resolution	2° (analog),	0.1 ° (digital)		
Alignment accuracy	± 2°			
Angle range - Tilt Mode	360 ° x 180 °	(X tilt, Y tilt)	Dual axis tilt ranges	
Angle range - Gimbaled Mode	360 ° x 90 ° (Y rotation, Y tilt)	Y rotation valid while of horizontal.*	Y tilt is within ± 45 °
			Angle	e range
Typical angular drift due to temperature			\pm 10 ° from any axis	± 45 ° from any axis (max error)
Values represent 1 sigma confidence in tilt	ture	15 C to +35 C	± 0.06 °	± 0.1 °
mode IND option	<u>Temperal</u> range	0 C to +70 C	± 0.3 °	± 0.6 °
		-40 C to +85 C	± 0.4 °	± 0.8 °
			Angle range	
Turnical angular drift due to temperature			\pm 10 ° from any axis	\pm 45 ° from any axis (max error)
Values represent 1 sigma confidence in tilt	ture	15 C to +35 C	± 0.3 °	± 0.6 °
mode LC option	<u>range</u>	0 C to +70 C	± 1.3 °	± 2.6 °
	Ten	-40 C to +85 C	± 1.9 °	± 4.8 °

*Note: Angle ranges measured with respect to deviations from inertial X,Y, Z reference frame.

OUTPUT CHARACTERISTICS

PARAMETER – HP AND LP VERSIONS	TYPICAL	NOTES
Update rate - HP option	40 Hz	Analog undete rate and Digital serial peaket rate
Update rate - LP option	5 Hz	Analog update fate and Digital serial packet fate
Warm up time from power on - S option	1.0 s	
Measurement settling time - S option	0.5 s	Angle itter and vibration are digitally filtered
Warm up time from power on - F option	0.2 s	Angle fitter and violation are digitally intered
Measurement settling time - F option	0.1 s	
Analog output resolution	8 bit	9 bit actual resolution after PWM reconstruction filter.
PWM modulation frequency	5 kHz to 20 kHz	
PWM reconstruction filter bandwidth	10 Hz	Single pole RC.
Output impedance	10 kΩ	

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SQ-SI2X-360DA

SOLID-STATE WIDE RANGE MEMS INCLINOMETER

360 ° x 180 ° DUAL AXIS, SERIAL AND ANALOG OUTPUT

PARAMETER – ULP VERSION	TYPICAL	Notes
Update rate - ULP option	On demand up to 20 Hz	Serial output only. Analog output disabled.

PIN CONFIGURATION

Pin	SIGNAL NAME	USAGE		
1	Ground			
2	UART Transmit	Digital Output – UART transmit line. Push-pull (not open collector). If not used, solder to open circuit for mechanical stability. Do not connect to GND or current drain will increase.		
3	UART Receive	Digital Input – UART receive line. If not used, solder to V+.		
4	Baud Select	Digital Input – HP and LP version only. High selects high baud rate, Low selects low baud rate. If not used, solder to V+.		
5	+V _{cc} Supply			
6	X Tilt / Y Rotation Output	Analog Output – If not used, solder to open circuit for mechanical stability. Do not connect to GND or current drain will increase.		
7	Y Tilt Output	Analog Output – If not used, solder to open circuit for mechanical stability. Do not connect to GND or current drain will increase.		
8	Tilt Mode / Gimbaled Mode Select	Digital Input – High (or open) selects Tilt Mode, Low selects Gimbaled Mode. If not used, solder to open circuit for mechanical stability.		
9	Noise Estimator	Solder to open circuit for mechanical stability. Do not connect to GND		
10	NC	Solder to open circuit for mechanical stability. Do not connect to GND.		
11	Self-Test	Solder to open circuit for mechanical stability. Do not connect to GND		
12	Resolution Select	Solder to open circuit for mechanical stability. Do not connect to GND		
13	Flip X-Y	Solder to open circuit for mechanical stability. Do not connect to GND		
14	NC	Solder to open circuit for mechanical stability. Do not connect to GND		
15	/Reset & Prog 1	Digital Input – Active low reset. Bring low for >10 mS to reset device. If not used, solder to open circuit for mechanical stability. Do not connect to GND. Also used for FLASH programming.		
16	Prog 2	Digital Input – If not used, solder to open circuit for mechanical stability. <u>Do not</u> connect to GND. Also used for FLASH programming.		
17	NC	Solder to open circuit for mechanical stability. Do not connect to GND		
18	NC	Solder to open circuit for mechanical stability. Do not connect to GND		

*Note: Grey boxes indicate that a signal is available only on a custom application basis. NC means "no connection".



SQ-SI2X-360DA

SOLID-STATE WIDE RANGE MEMS INCLINOMETER

 $360\ensuremath{\,^\circ}\xspace{}x\,180\ensuremath{\,^\circ}\xspace{}$ dual axis, serial and analog output

SQ-SI2X-360DA SERIES PACKAGE



DIMENSIONS

DIMENSION	MILLIMETERS	INCHES	DESCRIPTION	NOTES
Т	10.16	0.40	N/A	Pin center to center
L	25.40	1.00	Side length	
Е	2.54	0.10	Pitch	Pin center to center
D	0.80	0.032	Pin diameter	
DD	1.00	0.040	Hole diameter	
Ν	1.63	0.064	PCB thickness	
Н	8.64	0.34	Ortho board height	
Р	3.30	0.13	N/A	
S	20.32	0.80	Pin row spacing	Same as ortho board width

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SQ-SI2X-360DA

SOLID-STATE WIDE RANGE MEMS INCLINOMETER

 $360\,^{\rm o}$ x $180\,^{\rm o}$ dual axis, serial and analog output

DESIGN, LAYOUT, AND ASSEMBLY CONSIDERATIONS

- 1. Since the device is a subassembly of surface mount components, it is not suitable for automatic assembly or wave soldering.
- 2. Hand soldering of pins or SMT pads is specified for 3 seconds at 218 °C.
- 3. Pins labeled NC (no connect) should be soldered to open connection pads / pins for mechanical stability.
- 4. The designer should test the device's output voltage through its entire desired angle range during prototyping to ensure that it is working properly in the application.

SERIAL INTERFACE: HP AND LP VERSIONS^{*}

UART FORMAT: 8-N-1

8 data bits, 1 stop bit, no parity, no flow control: 115,200 baud or 57,600 baud, pin-selectable. (Available in 19,200 baud by special order.)

One byte commands can be sent from the host to control various functions of the device. The following commands can be sent to the devices via the UART. The data encoding is HEX, not ASCII.

INTERROGATE

0x01 (Interrogate Mode command)

The inclinometer responds with one data packet [10 bytes] after receiving the Interrogate Mode command. The maximum delay between a request and the data packet response is 1 Update Period. The host should not issue a new Interrogate Mode command before it has received a response to a previous Interrogate Mode command.

STREAM

0x02 (Stream Mode command)

The inclinometer begins sending data packets [10 bytes] continuously at the given Update Rate. The maximum delay between a request and the first data packet response is one Update Period.

RESET

0x83 (Reset command) The inclinometer initiates its Power-on Reset sequence (see Power-on Reset below).

RESET SOURCES

Power-on Reset and RST pin

When the inclinometer is disconnected from power it reverts to its default settings in Interrogate Mode. It transmits 1 data packet [10 bytes] after its Warm Up time to indicate that measurements are stabilized.

*	For the ULP version see the document	"SO-SI2X ULP Addendum"	' available at http://www.signalquest.com
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 $360\,^{\rm o}$ x $180\,^{\rm o}$ dual axis, serial and analog output

SERIAL PACKET FORMAT: HP AND LP VERSIONS

	Вуте	TILT MODE	GIMBALED MODE	Notes
ıder	0	Sync byte 1	Sync byte 1	0xFE
Неа	1	Sync byte 2	Sync byte 2	0xFE
	2	X Tilt (high byte)	Y Rotation (high byte)	
oad	3	X Tilt (low byte)	Y Rotation (low byte)	Format: 16-bit, unsigned integer $Output Value = Measured Angle \times 10.$
	4	Y Tilt (high byte)	Y Tilt (high byte)	For example, a measured angle of 127.5 ° results in an outp value of 1275.
Payl	5	Y Tilt (low byte)	Y Tilt (low byte)	
	6	Factory	Factory (high byte)	Undefined
	7	Factory	Factory (low byte)	ondenned
ksum	8	Checksum (high)	Checksum (high)	Format: 16-bit, unsigned integer sum of the 16 bit unsigned
Check	9	Checksum (low)	Checksum (low)	two sync bytes (0xFE 0xFE).

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SOLID-STATE WIDE RANGE MEMS INCLINOMETER

 $360\ensuremath{\,^\circ}\xspace{}x\,180\ensuremath{\,^\circ}\xspace{}$ dual axis, serial and analog output

EXAMPLE OUTPUT: HP AND LP VERSIONS*

EXAMPLE SUPPLY VOLTAGE				
$+V_{cc}$	3.300	V		
Sensitivity	0.01289	V/bit		
Scale factor	0.00731	V/deg		
Offset value	0.3300	V		
Max value	2.9552	V		



EXAMPLE ANGLES	OUTPUT (BITS)	OUTPUT (V)
0	26	0.335
10	31	0.399
20	37	0.477
30	43	0.554
40	48	0.618
50	54	0.696
60	60	0.773
70	65	0.837
80	71	0.915
90	77	0.992
100	82	1.057
110	88	1.134
120	94	1.211
130	99	1.276
140	105	1.353
150	111	1.430
160	116	1.495
170	122	1.572
180	128	1.650
190	133	1.714
200	139	1.791
210	145	1.869
220	150	1.933
230	156	2.010
240	162	2.088
250	167	2.152
260	173	2.230
270	179	2.307
280	184	2.371
290	190	2.449
300	196	2.526
310	201	2.591
320	207	2.668
330	213	2.745
340	218	2.810
350	224	2 887

*	[*] For cumply voltages oth	or then 2 2V and the	doormont "In a	lin om stor Worlich og	" available at http	n.//www.aignola	mant age
	For suppry voltages of	iei uiaii 5.5 v see uie	accument me	infometer worksnee	t avanable at http	J.// WWW.SIgnalo	juest.com

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SQ-SI2X-360DA

SOLID-STATE WIDE RANGE MEMS INCLINOMETER

 $360\,^{\rm o}$ x $180\,^{\rm o}$ dual axis, serial and analog output

ORIENTATION

TERMINOLOGY

Gravity means a vector pointing from the device toward the center of the earth.

X means a vector parallel to the white silkscreen arrow "X" printed on the main circuit board.

Y means a vector parallel to the white silkscreen arrow "Y" printed on the main circuit board.

Z means a vector passing through the white silkscreen dot "Z" printed on the main circuit board, at 90° to the board.

Horizontal means the silkscreen arrow is pointing at a right angle to gravity.

Straight Down means the silkscreen arrow is parallel to gravity.

Straight Up means that the silkscreen arrow is anti-parallel to gravity (i.e. pointing toward the sky).

Plumb Line is a line with a weight on the end hanging straight down.

<u>Tilt Mode</u>

In Tilt Mode the X Tilt and Y Tilt angles are measured between gravity and the white silkscreen arrows printed on the main circuit board. If you passed a Plumb Line through the inclinometer's X, Y, Z origin, the X and Y Tilt angles could be measured by placing a protractor's straight edge on the plum line and then reading the angles made with each arrow.

Y Tilt = Pitch (first angle) X Tilt = Roll (second angle)

Holding Y Horizontal

When X is Horizontal and Z is <u>Straight Up</u>, X Tilt = 90 °. When X is Horizontal and Z is <u>Straight Down</u>, X Tilt = 270 °. When X is Straight Up, X Tilt = 180 °. When X is Straight Down, X Tilt = 0/360 °.

Holding X Horizontal

When Y is Horizontal, Y Tilt = 90°. When Y is Straight Up, Y Tilt = 180°. When Y is Straight Down, Y Tilt = 0°.

Gimbaled Mode

In both Tilt Mode and Gimbaled Mode, the Y Tilt measurement is identical. However, in Gimbaled Mode, the Y Rotation angle is defined as a rotation *about* the Y axis of the device. You will find that this is similar to X Tilt (in Tilt Mode) when near horizontal, but further from horizontal, the difference between these two measurement methods is quite pronounced.

For users familiar with Euler Angles, this measurement mode is equivalent to performing the Euler X-Y transformation on the Tilt Mode coordinates, and then adjusting the quadrants to be continuous. In Gimbaled Mode unlike Tilt Mode, there will be no numerical discontinuities near 0 and 180 degrees for X Tilt, when Y is not Horizontal.

IMPORTANT NOTES

- Tilt Mode angles are <u>not</u> generally equivalent to Gimbaled Mode angles. Tilting X up or down in the Tilt Mode coordinate system is <u>not</u> equivalent to making a rotation about the Y axis unless Y is fixed horizontally. The same is true for the X axis. Consult SignalQuest technical support and reference material on orientation reference frames.
- Users wanting to measure rotations about the inclinometer's Y axes rather than tilt angle with respect to gravity, should use the Gimbaled Mode coordinate system. To convert a dataset from Tilt Mode coordinates (the sensor's native output) to Gimbaled Mode coordinates, contact SignalQuest for application notes and sample software.
- Regardless of the coordinate frame used the inclinometer measures angles with respect to gravity. It <u>cannot</u> measure rotation about the gravity vector. All rotations about gravity are *invisible* to the sensor and are considered equivalent.

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 $360\,^{\rm o}$ x $180\,^{\rm o}$ dual axis, serial and analog output

ORDERING GUIDE

OPTIONS	CODE	Option	Notes
יז ר	-NR	No onboard regulator	Special order only
owe gulat	-3.0R	3.0 V onboard regulator	Special order only
Les P	-3.3R	3.3 V onboard regulator	Standard version (stock)
lge	-HMP	Horizontal mount package	Fits into standard 0.100" grid circuit board
packa	-VMP	Vertical mount package	Available for SQ-SI family only
Pin	-NP	No pins installed	Fits inside potting box enclosures (SQ-ENCL-1)
nce	-HP	High performance	Better if power consumption is not a primary concern
formar option	-LP	Low power	Better if low power consumption is critical
Per	-ULP	Ultra low power	Pre-release version available now
х.	-IND	High accuracy	Suitable for industrial applications needing precise measurement
Accuracy	-LC	Low cost	Suitable for high volume, lower accuracy, cost sensitive applications
g option nd LP version y)	-S	500 mS settling time	Better noise rejection, slower response time – This model uses a 0.5 second moving average filter to provide digital damping. This reduces the impact that spurious accelerations and vibrations have on the angle reading. This model will reject noise better than the "F" model, but with the trade off of a slower response
gniqr HP a onl	Г		time.
Dan (used for I	-F	100 mS settling time	This model uses a 0.1 second moving average filter to provide digital damping. This model will respond more quickly to changes in angle than the "S" model, but with the tradeoff of poorer noise rejection.
RoHS (lead free)	-Е	RoHS complaint, lead free	
Other option	-Custom	Customer-specific requirements	Please contact SignalQuest if you require an option not listed in this table. For example, various baud rates, setting times, update rates and voltage regulator options may be available on request.

***Note:** "S" and "F" options only apply to HP and LP versions.

EXAMPLE PART NUMBER

SQ-SI2X-360DA-3.3R-HMP-IND-HP-S

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ACCESSORIES

PART NUMBER	DESCRIPTION					
SQ-USB2-TTL	 Self-powering USB cable used to directly connect device to a PC. 					
	 Installs a "virtual COM port" on host PC (i.e. COM 3). 					
	 Converts PC voltage levels to device voltage levels and supplies power. 					
	 Allows multiple devices to be easily connected to a single computer. 					
	 Compatible with SignalVIEW real time display and data logging software. 					
	 DLL provided for custom application development in VC++, C#, VB etc 					
SQ-RS232-TTL	 Same as above cable, but external power is required for devices without –LP option. 					
SQ-ENCL-1	 Potting box enclosure. Fits models without pins installed (-NP option). Order one if using SQ- 					
	SI family or two if ordering SQ-SI2X family.					

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SQ-SI2X-360DA

Solid-State Wide Range MEMS Inclinometer 360 $^{\circ}$ x 180 $^{\circ}$ dual axis, serial and analog output

LIMITATIONS AND WARNINGS

LIFE SAFETY

This product is not designed for use in life support and/or safety equipment where malfunction of the product can reasonably be expected to result in personal injury or death. Buyer uses this product in such applications at Buyer's own risk and agrees to defend, indemnify, and hold harmless SignalQuest, LLC from any and all damages, claims, suits, or expenses resulting from such misuse.

DYNAMIC ENVIRONMENTS

The device is designed to be used to measure angles in a quasi-static environment where external vibrations and accelerations are kept to a minimum. Digital and analog signal processing methods are employed to reduce the effects of transient acceleration and small vibrations on the angle reading; however, under dynamic conditions where external accelerations or vibrations are present, the sensor's performance may be degraded.

VARIATIONS IN EARTH'S GRAVITY

This device is designed to be used near the earth's surface only. Substantial changes in gravity will degrade the performance of the sensor. This device is not intended or qualified to be used in aviation.

TESTING

The performance of each system is verified through build-time testing. Each system is tested before and after factory calibration to ensure reliable performance.

SYSTEM INTEGRATION TESTING

Thorough testing should be carried out prior to product release to ensure system integration has not introduced unforeseen problems. The system integrator assumes the ultimate responsibility for the safety of the target application.

NOTICE

Information furnished by SignalQuest, Inc is believed to be accurate and reliable. However, this document may contain ERRORS and OMMISIONS. Accordingly, the design engineer should use this document as a reference rather than a strict design guideline and should perform thorough testing of any product that incorporates this or any other SignalQuest product. No responsibility is assumed by SignalQuest, LLC for this use of this information, or for any infringements of patents or other rights of third parties that may result from its use. Specifications are subject to change without notice. No license is granted by implication or otherwise under any patent or patent rights of SignalQuest, LLC Trademarks and registered trademarks are the property of their respective companies.

FURTHER INFORMATION

For pricing, delivery, and ordering information, please contact SignalQuest at (603) 448-6266 For updates on this and other documents, visit our website at <u>www.signalquest.com</u>

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